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The Evolution of Blood Pressure Limits and the Presentation of New Ranges for Normal People

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In 1902, Potain published the first extensive work on blood pressure and its limits, *La Pression Arterielle de l'Homme*.[1] Although his readings to-day are considered too high, because of the technique employed, the book has great historical interest. This was the first time that blood pressure levels were correlated with factors which might influence them, such as age, sex, weight and altitude.

The historical data presented below may be considered more or less accurate since they were obtained with standardised apparatus of the type used at the present time. In 1907, Theodore C. Janeway, of New York, published a monograph, *The Clinical Study of Blood Pressure*,[2] based on his own and some of his famous father's findings. He stated that a blood pressure above 145 mm. before middle age, or 160 mm. thereafter, was definitely abnormal if constantly present as the average reading.

About 1910, Brunton [3] of England and Cook [4] of Johns Hopkins lowered these limits to 135 mm. up to middle life, and 145 to 150 mm. thereafter. In 1915, Janeway [5] accepted these new criteria. We believe that physicians generally accepted 150 mm. mercury as the upper limit of normal systolic pressure in people over middle age, largely because of Janeway's great reputation.

In the past four decades a number of life insurance companies have presented their statistics. These have received wide publicity and have played an important role in establishing the limits of normal blood pressure accepted to-day. In a study by Fisher [6] based on an analysis of 65,000 accepted risks, the maximum acceptable systolic pressure was fixed at 131 mm. mercury at the age of 16 and at 151 mm. mercury at the age of 65. From an insurance study of 150,000 men who were apparently healthy, Symonds [7] concluded that the normal systolic blood pressure in males under 40 years was below 140 mm. mercury. A number of other studies, based on insurance company statistics, reported 150 mm. mercury as the maximal normal systolic pressure.[8]

These insurance company statistics cannot be accepted in clinical medicine because they are based on a very select part of the entire population and because they are concerned primarily with group prognosis and mortality. They are, therefore, not entirely applicable to the relationship between blood pressure readings and the individual expectation of life.

Yet these statistics form the basis for the accepted limits of blood pressure at the present time. However, it has been a common observation that people with blood pressure readings above the commonly accepted limits may live out their normal life span without complications related to their blood pressure. Bechgaard [9] followed 1,000 patients with blood pressures higher than 180 systolic and 100 diastolic for a period ranging from 4 to 11 years. Some had pressures as high as 240/130! He found that half of them were in good health and one-fourth were symptom-free at the end of this period. He noted that excess mortality from hypertension definitely diminished with advancing age. Blood and Perera,[10] likewise, reported that long survival of people with so-called "high" blood pressure is far from rare, and that elevated arterial pressure may not be associated with symptoms. Burgess [11] followed 100 patients with blood pressures of 180/100 or more for at least eight years. He concluded that even severe hypertension, if it had been present for eight years or more and was not associated with well-established cardiac or renal disease, usually did not signify a poor prognosis. Such patients, indeed, may live to within three to four years of their life span.

These results suggested that the accepted limits of normal blood pressure limits were too low and should be liberalised. Furthermore, several published studies of blood pressures in normal persons indicated that the normal limits may be higher. One of the first to publish data not conforming to the widely accepted limits of norm, 150/90, was Alvarez in 1923.[12] In a routine examination of approximately 6,000 young, healthy college freshmen, he found 22 per cent. to have a systolic pressure above 140 mm. mercury. In a later study Diehl and Sutherland [13] found that 11.5 per cent. of 5,100 young college students without symptoms had a systolic pressure over 140 mm. mercury.

The studies cited (Bechgaard, Blood and Perera, Burgess, Alvarez, Diehl and Sutherland) were the handwriting on the wall. It seemed essential to investigate and, if necessary, to change some of the old concepts concerning the limits of blood pressure in normal people. This is not true only of the young and middle-aged, but particularly of the older age groups.

A number of investigations showed that systolic blood pressure normally increases with age. In 1923, Richter [14] studied 165 people between 60 and 89 years of age, excluding those suffering from nephritis and heart disease, and found that the average systolic pressure increased with age from 138 to 161 mm. mercury.

In 1928, Saller [15] determined the blood pressure of 4,200 patients in an out-patient clinic in Kiel. He excluded those with heart or kidney disease, anaemia, diabetes, fever and endocrinologic disturbances. Saller suggested that the increase in blood pressure in old age should be considered part of the ageing process and may be likened to other ageing changes, such as those in hair, teeth, eyes and libido. His results are indicated in Table I.

TABLE I.
Ranges of Blood Pressure as Determined by Saller in 4,200 Ambulatory Patients.

Age in Years.	Systolic B.P. Men.	Women.
21-35	98-144	99-138
35-47		100-155
48-53	96-154	100-190
54-59	97-159	104-196
60-67	93-173	102-216
68-89	86-186	112-222

The salient finding of Saller was a gradual increase in blood pressure after the age of 47. Between 68-89 years of age the range of systolic blood pressure in the male was found to be between 86-186 mm. mercury, while in the female it was from 112-222 mm. mercury. He did not claim that all blood pressures lying within these limits were normal. It was his conclusion, however, that if the blood pressure was not outside these limits, one could not be sure whether it would have any influence upon the length of life. Saller's study was very extensive and is cited in all papers on blood pressure in older age groups.

In a study published in 1937, Kylin [16] confirmed the rule that the normal blood pressure may be estimated by adding the age in years to 100 mm. mercury, thus acknowledging the increase of the pressure with increasing years. Furthermore, he fixed the maximum normal systolic blood pressure at 170 mm. mercury. It is interesting to note that this rule, which enjoyed wide popularity for a time and then was discarded, is again coming into vogue as a rough "rule of thumb."

In 1943, Master, Marks and Dack [17] published findings of 15,000 blood pressure readings in persons over 40 years of age, who formed a fairly representative group of the population. Using the definition of hypertension as 150/100 or over, they found that one-third of the male population and two-fifths of the female population 40 years of age and over were hypertensive. These proportions increase rapidly with age, so that high blood pressure is present in the majority of men 60 and over and in women 50 and over. Therefore they suggested the usual definition of hypertension might have to be changed, and the upper limit of normal, in middle and later life, revised upward. Several other studies tended to substantiate this point of view: Wishard,[18] Russek,[19] Gavey.[20]

George Perera and Dana Atchley [21] have emphasised the wide and inconsistent normal range of blood pressure. They pointed out that a systolic blood pressure between 160-180 mm. mercury and a diastolic blood pressure between 90-100 mm. mercury may be found in normal aged persons. East and Bain,[22] in 1948, employed a limit of 160 mm. systolic, while Evans,[23] also in 1948, used 180 mm. systolic and 110 mm. diastolic.

The material heretofore presented includes a large number of studies made by many physicians in different countries and in large and varied sections of the population. From these studies it was clear that it was essential to establish new limits of normal systolic pressure.

DIASTOLIC PRESSURE

Before 1900 the main interest in blood pressure centred about the systolic pressure. In 1907, Janeway [2] stated that a determination of the systolic pressure alone was necessary routinely and that the diastolic was useful only under certain circumstances. However, to-day the pendulum has swung the other way and more attention is paid to the diastolic pressure than to the systolic.

The insurance company statistics of the 1920's were the basis for the acceptance of 95 mm. mercury as the upper normal limit of diastolic pressure. However, Boynton and Todd [24] found that about 4,500 (5 to 7 per cent.) of 75,000 presumably healthy students under 40 years of age had a diastolic pressure of over 90 mm. mercury.

Master, Marks and Dack [17] also found that the diastolic pressure rose with age. Over one-quarter of those tested between the ages of 60-69 had a diastolic pressure of over 95 mm. mercury. The increase of the diastolic pressure with age is less marked than the systolic. This is in keeping with the well-known fact that the pulse pressure increases with age. It was evident,

therefore, that there was a need for establishing new normal limits of diastolic pressure as well as of systolic pressure.

PRESENTATION OF NEW LIMITS

It has thus been clearly shown that clinicians and investigators concerned with the average individual patient and not with selected groups have from time to time felt the need of altering the accepted normal limits of blood pressure. Two methods for the establishment of new limits of normal blood pressure were available. One was to follow the course of a large number of people with what were considered to be normal and elevated blood pressure for many years, until death. The use of this method was obviously limited by the extreme difficulty of the undertaking and the expense entailed. Even at post-mortem examination it is often very difficult to say whether the cause of death is related to the elevated blood pressure. The other method, which we have employed, consisted in surveying the blood pressure of large representative groups of the healthy population. This is a more advantageous technique. It has been employed by many physicians to obtain averages, ranges and trends of blood pressure, correlated with age and sex, etc. However, none of these physicians had actually presented limits defining normal and abnormal blood pressure.

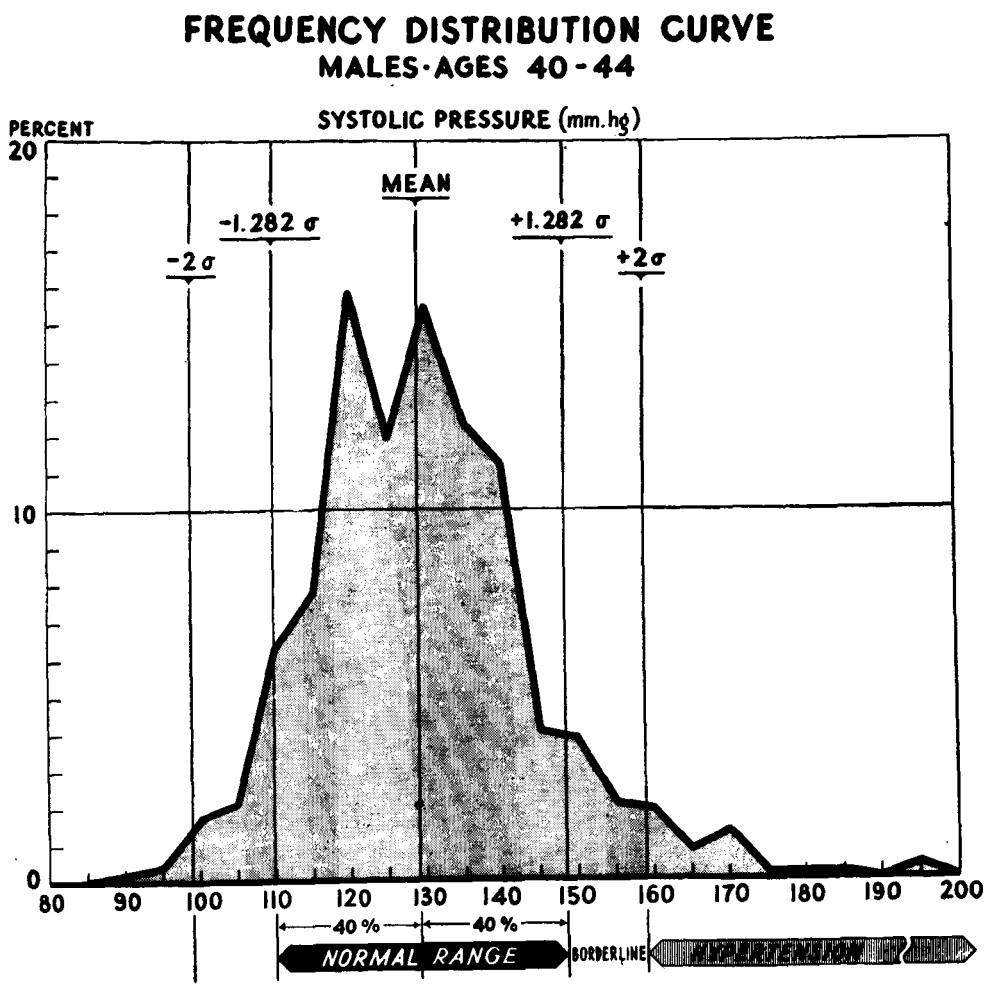

Fig. 1

During World War II the opportunity arose to obtain blood pressure readings of 74,000 persons who were in average good health and able to work regularly. These readings were obtained in industrial plants, in various sections of the country, in as representative a group as

possible. The subjects were executive, clerical and manual workers, skilled and unskilled, male and female. Detailed correspondence with the numerous physicians involved, as well as personal observation, convinced us that the figures obtained were reliable. Where any doubt existed, the data were not used. Because of the large volume of material gathered, random samples of at least 500 readings of each sex, in each five-year age group, were tabulated. The data thus obtained covered 15,706 persons. The results of this survey were subjected to statistical analysis and published recently by Master, Dublin and Marks.[25]

The findings were analysed as a whole, and specifically according to sex, age, weight and height of the subjects. As is well known, most measurable natural characteristics give a fairly symmetrical normal curve of distribution. In analysing the measurements of such a variable factor as blood pressure, however, difficulties are encountered and a perfectly smooth distribution curve cannot be expected. Yet, in each age group and sex, the frequency distribution of the blood pressure levels yielded a fairly formal curve. (See Fig. I distribution curve.)

The range of the normal blood pressure is defined statistically and is based upon the distribution of the readings around the mean, according to age and sex. The closer a reading is to the average or mean, the greater is the chance of its being normal; the further it is from the average or mean, the greater is the likelihood of its being abnormal.

The standard deviation sd. is the yardstick commonly used to measure the amount of deviation from the mean. Usually about two-thirds (68.27 per cent.) of all observations are found to be within one standard deviation from the mean (mean $\pm$ sd.). Usually, too, about 95 per cent. of all observations are found to be within two times the standard deviation from the mean (mean $\pm$ 2 sd.). Since physiologic normality cannot be defined, the statistical determination of the normal blood pressure range is necessarily an arbitrary one. It may be assumed that any reading within one standard deviation from the average (68.27 per cent.) is within normal range. Indeed, the normal range may reasonably be extended to include 80 per cent. of all observations—40 per cent. on either side of the mean ($\pm$ 1.282 sd.). (Figure I.) All blood pressure readings found to be beyond two times the standard deviation from the mean are probably abnormal. These include 2.5 per cent. of all the observations at either extreme. The area between the limits of the normal and the probably abnormal constitutes a narrow borderline.

The graphs in Figures I and II are based on the actual computations. Since blood pressure readings are not exact, some degree of modification of the computed values is necessary. This has been made. Tables II and III summarise

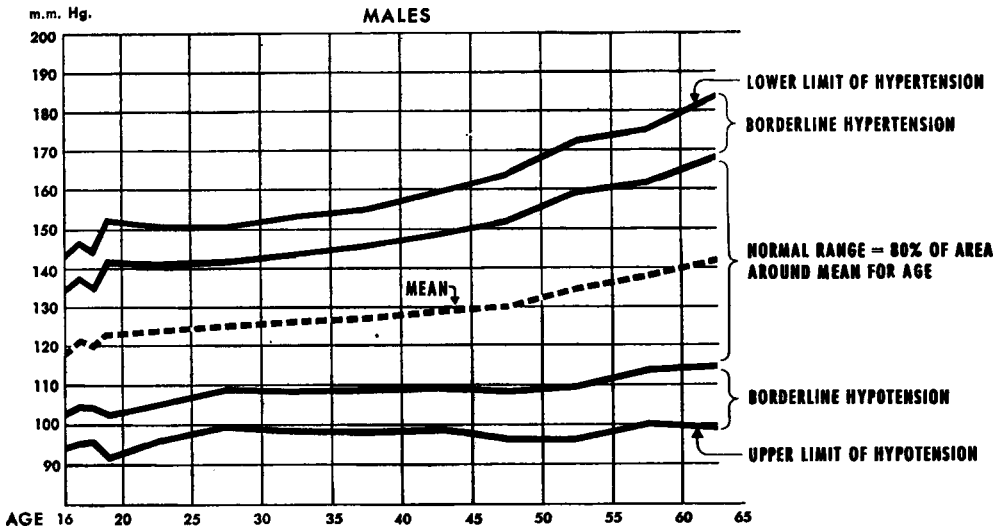

Fig. 2

the results of this study. They indicate the normal range of systolic and diastolic pressure by sex and age, and the limits beyond which the readings are probably abnormal.

The tables show that the range of systolic pressure increased gradually with age. They also show that the range and limit of normal systolic pressure start at a slightly lower level in women as compared to men and continue to be lower in women until the age of 40, when they become equal in both sexes. After the age of 50 the normal limit is slightly higher in women than in men. Thus, at 16 years of age, the lower limit of systolic hypertension among males is 145 mm. mercury (normal range 100-130). At 55-59 years of age the lower limit of systolic hypertension among males is 180 mm. mercury (normal range 115-165), and among females it is 185 mm. mercury (normal range 110-170). All the readings between the maximum limit of the normal range and the lower limit of systolic hypertension are considered as borderline. They may be normal or hypertensive, depending upon the clinical status of the patient (history, physical examination, cardiac enlargement, kidney disease, etc.).

The same gradual increase is found in the diastolic readings also, but here the increase is less marked. Thus at 16 years of age, 90 mm. mercury (normal range 60-86), and at 64 years of age, 110 mm. mercury (normal range 70-100) are given as the lower limits of diastolic hypertension.

In comparing our "average" blood pressures with those given by two other investigators, [26 27] it is evident that our "mean" pressures occupy a mid-position between those of the other two.

MEAN BLOOD PRESSURE READINGS IN SELECTED STUDIES

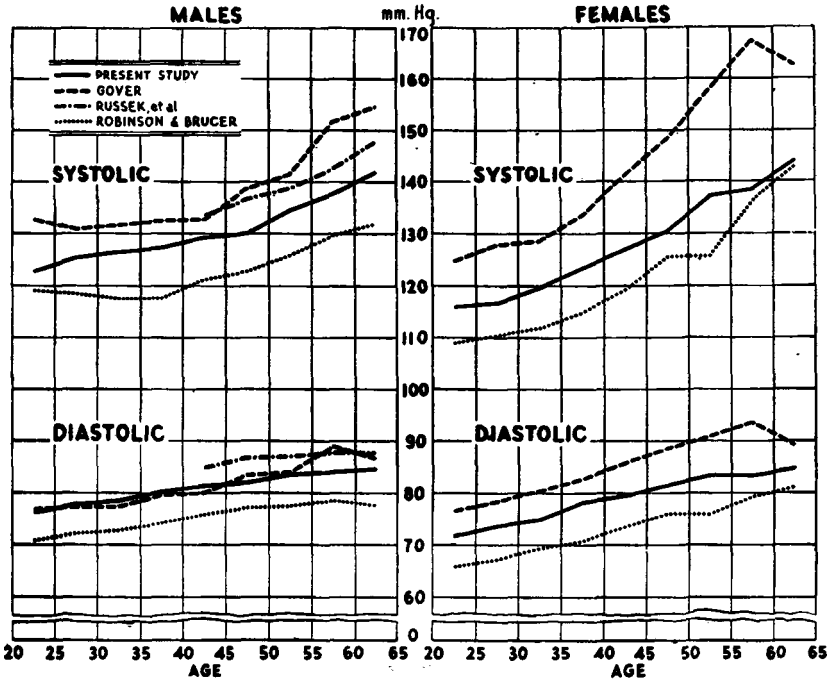

Fig. 3

(Figure III.) This suggests that our blood pressure readings are not too high and can be accepted with confidence.

DISCUSSION

The predominant ideas about normal blood pressure limits have been largely on data relating blood pressure readings to group mortality figures. These studies have been issued mainly by the life insurance companies. The practice of using selected group mortality rates to establish normal limits of blood pressure is improper, for these limits are of little aid in determining the significance of the blood pressure reading in the individual case. From time to time clinicians

have pointed out the fallacy of accepting these rigid criteria to delimit the normal from the abnormal. Accordingly, the problem of obtaining new limits of normal and abnormal blood pressure was paramount. We have analysed and presented data, based on 74,000 blood pressure readings, which raise the normal limits of blood pressure usually accepted to-day.

Based on these new limits, the evaluation of blood pressure readings must not be interpreted too literally. The blood pressure is only one factor to be considered in the determination of the clinical status of the patient, and it must be evaluated in the light of the history, physical examination, eyeground changes, x-ray examination, function tests of the heart, etc.

The acceptance of the new limits may have an effect in many fields. In medicine it may be necessary to revise concepts based on the correlation between moderate "hypertension," according to the old criteria, and various conditions —coronary artery disease and coronary occlusion, cardiac enlargement, arteriosclerosis, and diabetes. Many of these supposed relationships are being studied, using the new limits. The results will be presented at a future date.

In other fields too the importance of the new limits is considerable. At the present time, not only physicians but also laymen have become alert to the importance and significance of the blood pressure reading. In clinical practice every physician sees many patients who are greatly disturbed by blood pressure levels which are moderately "hypertensive." With the new limits, these patients will be relieved by the knowledge that their blood pressure is within normal limits and is not incompatible with an average expectation of life. In addition, much therapy now given to lower the blood pressure of these patients will no longer be considered necessary.

The application of new limits will also have a widespread effect in industrial and military medicine, and in the life insurance field. In industry many men, particularly those over middle age, who have been rejected because of so-called hypertension, will have the opportunity to become gainfully employed. Present concepts of hypertension, as related to Workmen's Compensation, will have to be revised. These changes will mark important gains for the individual and for the community in which he lives. In the military field a number of rejectees may be considered fit for service when the new criteria are used; this will allow better utilisation of our manpower.

It is not at all our intention to minimise the importance of true hypertension and its complications. The effects of the malignant form, in particular, are only too well known. There must be no slackening of the effort to learn the causes of high blood pressure and to develop means of preventing or curing the condition.

The tables and figures are taken from *Normal Blood Pressure and Hypertension, New Definitions*, Master, A. M., Garfield, C.I., and Walters, M.B. Lea & Febiger, Philadelphia, U.S.A., 1952.

TABLE II

Normal Range and Limits of Hypertension.

Systolic Age.	Normal Range. Male.	Normal Range. Female.	Hypertension Lower Limit. Male.	Hypertension Lower Limit. Female.
16	105-135	100-130	145	140
17	105-135	100-130	145	140
18	105-135	100-130	145	140
19	105-140	100-130	150	140
20-24	105-140	100-130	150	140
25-29	108-140	102-130	150	140
30-34	110-145	102-135	155	145
35-39	110-145	105-140	160	150
40-44	110-150	105-150	165	165
45-49	110-155	105-155	170	175
50-54	115-160	110-165	175	180
55-59	115-165	110-170	180	185
60-64	115-170	115-175	190	190

TABLE III

Normal Range and Limits of Hypertension.

Diastolic Age.	Normal Range. Male.	Normal Range. Female.	Hypertension Lower Limit. Male.	Hypertension Lower Limit. Female.
16	60- 86	60- 85	90	90
17	60- 86	60- 85	90	90
18	60- 86	60- 85	90	90
19	60- 88	60- 85	95	90
20-24	62- 88	60- 85	95	90
25-29	65- 90	60- 86	96	92
30-34	68- 92	60- 88	98	95
35-39	68- 92	65- 90	100	98
40-44	70- 94	65- 92	100	100
45-49	70- 96	65- 96	104	105
50-54	70- 98	70-100	106	108
55-59	70- 98	70-100	108	108
60-64	70-100	70-100	110	110

BIBLIOGRAPHY

(1) Potain, P C. E. La pression arterielle de l'homme a l'etat normal et pathologique. Paris, Masson, 1902.

(2) Janeway, T. C. The clinical study of blood pressure. New York and London, D. Appleton Co., 1907.

(3) Brunton (Sir), T. L. Blood pressure in man: its estimation and indications for treatment. *Brit. Med. J.* 2:64-67, 1909.

(4) Cook, H. W. Blood pressure in prognosis. *Med. Rec.* 80: 959-68, 1911.

(5) Janeway, T. C. Important contributions to clinical medicine during the past thirty years from the study of human blood pressure. *Johns Hopk. Hosp. Bull.* 26-341-50, 1915.

(6) Fisher, J. W. Personal communication. in Norris, G. W., Bazett, H. C., and McMillan, T. M. Blood pressure and its clinical applications. 4 ed., Philadelphia, Lea & Febiger, 1927, p. 127.

(7) Symonds, B. The blood pressure of healthy men and women. *J. Amer. Med. Assoc.* 80-232-36, 1923.

(8) Goepp, R. M. Blood pressure from the life insurance standpoint, Med. Rec. 91-801-03, 1917; and Blood pressure as a prognostic factor, *Penn. Med. J.* 22-295-301, 1918-19.

(9) Bechgaard, P. Arterial hypertension; follow-up study of one thousand hypertensives. Acta Med., Scand. Supp. 172; 3-358, 1946.

(10) Blood, D. W., and Perera, G. A. Hypertensive vascular disease; duration of life in selected series. *Amer. J. Med.* 4: 83-88, 1948.

(11) Burgess, A. M. Excessive hypertension of long duration. *New Engl. J. Med.* 239: 75-79, 1948.

(12) Alvarez, W. C. Blood pressures in fifteen thousand university freshmen. *Arch. Intern. Med.* 32; 17-30, 1923.

(13) Diehl, H. S., and Sutherland, K. H. Systolic blood pressures in young men, including a special study of those with hypertension. *Arch. Intern. Med.* 36-151-73, 1925.

(14) Richter, A. Uber Blutdruck in hoheren Alter. *Dtsch. Arch. klin. med.* 148: 111-20, 1925.

(15) Saller, K. Uber die Altersveranderungen des Blutdrucks. Z. ges. exp. Med. 58-683-702, 1928.

(16) Kylin, E. W. V. Der Blutdruck des Menschen. *Dresden.* Th. Steinkopff, 1937.

(17) Master, A. M., Marks, H. H., and Dack, S. Hypertension in people over 40. *J. Amer. Med. Assoc.* 121: 1251-56, 1943.

(18) Wishard, E. B. Medical responsibility in industrial health: given at the Institute of Geriatrics, sponsored by the Indiana University School of Medicine and the Indiana State Board of Health, Indianapolis, May, 1946.

(19) Russek, H. I., Rath, M. M., Zohman, B. L., and Miller, J. Influence of age on blood pressure; study of 5,331 white male subjects. *Amer. Heart J.* 32: 468-79, 1946.

(20) Gavey, C. J. The cardiology of old age. *Lancet* 2: 725-36, 1949.

(21) Perera, G. A., and Atchley, D. W. Hypertensive vascular disease, in Nelson new loose-leaf medicine, v. 1, 1949, pp. 239-63. (See p. 234.)

(22) East, C. F. T., and Bain, C. Recent advances in cardiology. 4 ed. Philadelphia, Blakiston, 1948, pp. 111, 114, 132, 133, 134.

(23) Evans, W. Cardiology. New York, Paul B. Hoeber, 1948, p. 204.

(24) Boynton, R. E., and Todd, R. L. Blood pressure readings of 75,258 university students. *Arch. Inter. Med.* 80-454-62, 1947.

(25) Master, A. M., Dublin, L. I., and Marks, H. H. The normal blood pressure range and its clinical implications. *J. Amer. Med. Assoc.* 143: 1464-70, 1950.

(26) Gover, M. Physical impairments of members of low-income farm families; variation of blood pressure and heart disease with age and the correlation of blood pressure with height and weight. *Pub. Hlth. Rep.* 63: 1083-1101, 1948.

(27) Robinson, S. C., and Brucer, M. Range of normal blood pressure statistical and clinical study of 11,383 persons. *Arch. Inter. Med.* 64: 409-44, 1939.